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Kaolin particle film associated with increased cotton aphid infestations in cotton

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Abstract

Highly reflective white kaolin-based particle film was sprayed on cotton, *Gossypium hirsutum* L. (Malvaceae), plots in south Texas during 2004 and 2005 to observe its effect on the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae). Populations of cotton aphids on the ventral surfaces of leaves in the kaolin-treated plots were greater than in non-treated control plots during both years. Alate cotton aphids were attracted less to white than to other pan trap colors, and parasitism by *Lysiphlebus* spec. (Hymenoptera: Aphidiidae) was either unaffected or greater in the kaolin-treated plots, hence these two factors (color and parasitism) do not explain the increased infestations in the treated plots. However, mean temperatures on the ventral surfaces of kaolin-treated cotton leaves were cooler than those of control leaves. The observed temperature difference where cotton aphids reside on cotton leaves is a potential reason for the greater infestations in the kaolin treatment plots. Our study demonstrates that applications of kaolin can exacerbate a pest infestation in cotton.

Introduction

The cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), is the most common aphid species infesting cotton, *Gossypium hirsutum* L. (Malvaceae), worldwide, but it has a wide host range including plants from more than 90 families (Ebert & Cartwright, 1997; Henneberry et al., 2000). Cotton aphids stylet feed from phloem on the undersides of cotton leaves. Damage to cotton results from leaf crinkling and accumulations of honeydew, and associated problems of sooty mold (Akey et al., 1989). Honeydew contamination causes problems in cotton lint processing at the gin and textile mill (Slosser et al., 1989; Ebert & Cartwright, 1997). Control of cotton aphids is usually accomplished by naturally occurring diseases or parasitoids, but occasionally chemical control is required (Phillips et al., 1980).

Kaolin is a white, porous, non-swelling, non-abrasive fine-grained platy aluminosilicate mineral $[Al_4Si_4O_{10}(OH)_8]$ that disperses in water and is chemically inert over a wide pH range. Coating grade kaolin is >90% pure and has a brightness quality of >85% (Harben, 1995). Injury to some crops caused by insects and pathogens can be reduced by coating plants with kaolin, a hydrophobic particle film (Glenn et al., 1999). The film makes the host plant visually or tactually unrecognizable, and particles adhering to the arthropod's body might impede movement and feeding (Glenn et al., 1999).

Application of kaolin particle film to orchard crops has resulted in the suppression of injury caused by pear psylla, *Cacopsylla pyricola* Foerster; spirea aphid, *Aphis spireacola* Patch; potato leafhopper, *Empoasca fabae* (Harris); codling moth, *Cydia pomonella* (L.); obliquebanded leafroller, *Choristoneura rosaceana* (Harris); root weevil, *Diaprepes abbreviatus* (L.); and twospotted spider mite, *Tetranychus urticae* Koch (Bar-Joseph & Frenkel, 1983; Glenn et al., 1999; Knight et al., 2000; Lapointe, 2000; Puterka et al., 2000; Unruh et al., 2000). In cotton, kaolin applied weekly or biweekly deters adult boll weevils, *Anthonomus grandis grandis* Boheman, from ovipositing on cotton squares in the Lower Rio Grande Valley of Texas (Showler, 2002). Also, kaolin-sprayed cotton leaves reduces beet armyworm, *Spodoptera exigua* (Hübner), oviposition, and larval feeding and survivorship (Showler, 2003). In kaolin-treated cotton field plots, cicadellid populations were reduced as well as *Orius* spp., wasps, and dipterans (Showler &

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Sétamou, 2004). The purpose of this study was to assess the effect of kaolin particle film on cotton aphid infestations in cotton.

Materials and methods

The kaolin was formulated as Surround™ wettable powder (Engelhard, Iselin, NJ, USA) processed to a bright white color of >85%, ≤2 μm particle diameter and coated with a proprietary synthetic hydrocarbon to impart hydrophobic quality. The standard field rate of 60 g of kaolin per liter of water was used in this study.

Twelve plots, each 0.025 ha in area [eight rows wide (row spacing = 1 m) × 30.4 m long] with a 1-m bare ground buffer between plots were arranged in a randomized complete block design on the grounds of the Kika de la Garza Subtropical Agricultural Research Center, TX, USA Cotton (var. DP5415RR) was planted on 2 March 2004 and on 8 March 2005. Pendimethalin (Prowl 3.3 EC, American Cyanamid, Parsippany, NJ, USA) at 924 g (active ingredient) per ha was applied by tractor immediately after planting, and weed control was thereafter conducted with a rolling cultivator, and by hand pulling. Irrigation occurred at the start of bloom (mid-May).

Beginning 24 March 2004 and 6 April 2005, before aphids were observed, kaolin solution was applied to six plots by tractor-mounted boom sprayer using 18 Teejet 8003E nozzles 1 m apart (each nozzle ~30 cm directly over the top of a row) at 42.3 l per ha, 3.5 kg cm^{-2}. Kaolin was reapplied weekly until after aphid sampling was completed during both years. Three weeks after the first application, two 47-cm drop nozzles were added to treat the sides of the plants in each row, as well as at the tops. The remaining six plots were non-treated controls. No insecticides or other pest-management tactics were applied in the kaolin-treated and control plots.

Ten upper (from the top four fully expanded) and 10 lower (from the bottom four) leaves from the canopy in each plot were visually examined and numbers of alate, wingless, and parasitized aphid mummies were counted at 11 consecutive weekly intervals from 31 March until 16 June 2004, and at 10 consecutive weekly intervals from 20 April until 29 June 2005. Numbers of cotton aphid-infested leaves in the upper and lower canopies were also recorded. Plant heights and numbers of nodes were recorded from six randomly selected plants in each plot on 1 April and 10 June 2004, and on 21 April and 30 June 2005.

Leaf surface temperature

Surface temperature data from the ventral surfaces of the third-from-the-top fully expanded leaves (n = 3) were recorded using a digital multimeter dual inputs thermometer (Omega HHM31, Bridgeport, NJ, USA) at 14:00 hours on 11 May and 3 June 2004, and on 25 May and 14 June 2005. The thermometer sensor was placed on the center of each sampled leaf for 10 min.

Parasitism

Aphid parasitism was evaluated when aphid populations were greatest on the cotton leaves, 17 May –18 June 2004 and 25 May –25 June 2005. Five cotton aphid-infested cotton leaves per plot were selected every week and the aphid population on each leaf was counted in situ. After counting the aphids, the leaves were excised, placed in separate paper bags and were transported to the laboratory with the aphids still on the leaves. Each leaf was individually maintained by inserting the petiole into a 5-ml plastic container with hydroponic solution and was kept in a Petri dish. The Petri dishes were monitored daily for parasitoid emergence. Parasitoids were removed and identified.

Leaf color

To assess cotton aphid attraction to colors, 30 plastic bowls, 12 cm in depth and 30 cm in diameter, were spray painted (Krylon, Dearborn, MI, USA) fluorescent yellow, forest green, or flat white, 10 bowls of each color. The bowls were fixed atop 1 cm thick metal rods that had been driven 30 cm into the soil on the edges of five cotton fields in Hidalgo County (two treatment replicates per field). The traps, 1 m over the soil surface, were filled halfway with water and two drops of detergent. Every 2 or 3 days from 7 April until 10 May 2004, and from 7 May until 6 June 2005, the contents of the traps were poured into plastic bags and alate cotton aphids were counted.

Statistical analyses

Plant heights and numbers of nodes per plant were analyzed using the two-sample t-test on each of the two sampling dates during each year. Leaf temperature data was analyzed using the two-sample t-test (Analytical Software, 1998). Numbers of living aphids on upper and lower cotton leaves and numbers of upper and lower leaves with at least one cotton aphid were log(x + 1) transformed and a two-way analysis of variance (ANOVA) was used with treatment and time as separate factors (Analytical Software, 1998). Percentages of total (cumulative) parasitized aphid mummies in the field over the sampling period were arcsine square root transformed before analysis using the two-sample t-test (Analytical Software, 1998). Parasite emergence data was analyzed using two-way ANOVA so that treatment and time effects were determined. Pan trap aphid data were analyzed using one-way ANOVA in accordance with a completely randomized design (Analytical Software, 1998). Means were separated using Tukey's

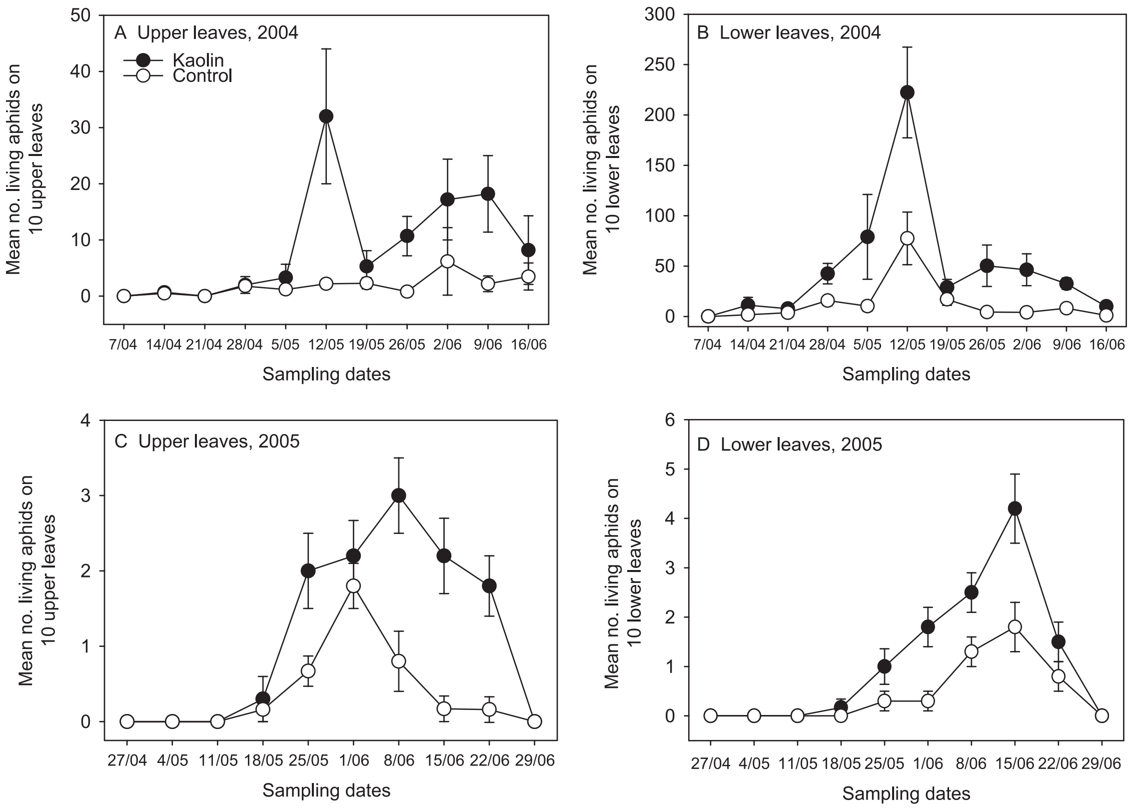

Figure 1 Mean (± SE) numbers of living cotton aphids found on 10 upper or lower cotton leaves in plots treated with kaolin particle film or left untreated as controls, Hidalgo County, Texas in 2004 and 2005; n = 6.

honestly significant difference (Analytical Software, 1998). Non-transformed data are presented.

Results

No treatment effects were detected for cotton plant heights and numbers of nodes per plant regardless of the sampling date. During 2004, the greatest cotton aphid populations, all wingless (alate numbers were negligible on leaves, <10 during each year in all 12 plots combined) occurred on kaolin-treated upper leaves at peak population levels on May 12, and greater numbers were also found in the kaolin treatment on May 26 and June 9 than in the untreated controls ($F_{1,100} = 17.29$, P = 0.0001; Figure 1A). The mean number of living aphids on lower leaves in 2004 was also greater in the kaolin treatment ($F_{1,100} = 63.80$, P<0.0001) with differences occurring on 6 of the 11 sampling dates (Figure 1B). During 2005, populations of living aphids on upper leaves in the kaolin treatment were higher than the control for 5 weeks starting, May 25 ($F_{1,90} = 20.38$, P<0.0001; Figure 1C). The mean number of living aphids on lower leaves in 2005 was also greater in the kaolin treatment ($F_{1,90} = 39.79$, P<0.0001) with differences beginning on May 25 and lasting until after peak populations were observed on June 15 (Figure 1D).

More leaves were infested with cotton aphids in the kaolin plots than in the untreated controls during 2004 (upper leaves: $F_{1,100} = 10.46$, P = 0.0017; lower leaves: $F_{1,100} = 37.36$, P<0.0001) and 2005 (upper leaves: $F_{1,90} = 20.38$, P<0.0001; lower leaves: $F_{1,90} = 41.39$, P<0.0001). Greater numbers of infested leaves occurred when numbers of cotton aphids increased, and peaks for both occurred at approximately the same times. Significant time effects were detected on upper (2004: $F_{10,90} = 31.82$, P<0.0001; 2005: $F_{9,90} = 48.54$, P<0.0001) and lower (2004: $F_{10,90} = 27.33$, P<0.0001; 2005: $F_{9,90} = 41.73$, P<0.0001) leaves for numbers of cotton aphids and for numbers of leaves infested in the upper (2004: $F_{10,90} = 32.66$, P<0.0001; 2005: $F_{9,90} = 41.29$, P<0.0001) and lower (2004: $F_{10,90} = 48.36$, P<0.0001; 2005: $F_{9,90} = 38.21$, P<0.0001) parts of the plant canopies. These differences reflect the gradual increases and declines normally associated with cotton aphid populations over the cotton-growing season (Figure 1A–D).

Table 1 Mean (± SE) cotton leaf surface temperatures (°C) on the undersides of leaves (n = 3 randomly selected leaves per plot) as affected by kaolin application to the upper sides, May and June of 2004 and 2005

	2004		2005	
Treatment	May	June	May	June
Kaolin	29.9 ± 0.4a	32.2 ± 0.2a	33.7 ± 0.3a	36.7 ± 0.6a
Control	31.2 ± 0.7a	33.9 ± 0.3b	35.3 ± 0.4b	39.7 ± 0.7b
t-value	1.58	5.12	3.29	3.38
P-value	0.189	0.007	0.030	0.027

Values followed by the same letter within a column are not significantly different at P<0.05 (two-sample t-test, d.f. = 1,4).

Temperature

The ventral surfaces of cotton leaves in the kaolin treatment were significantly cooler by 5% on the June 2004 sampling date. Temperature gradients were 4.5 and 7.6% on the May and June 2005 sampling dates, respectively (Table 1).

Parasitism

In the parasite emergence assay, *Lysiphlebus* spec. (Hymenoptera: Aphidiidae) was the only parasitoid found attacking cotton aphids during our study. Parasitism levels gradually declined from 59% on 17 May to 4% on 9 June in the control, and from 65 to 19% in the kaolin treatment during 2004 (Figure 2). Both treatment ($F_{1,337}$ = 23.11, P<0.0001) and time ($F_{5,337}$ = 13.01, P<0.0001) effects were detected. In 2005, no differences between treatments in terms of parasitism were observed, and time effects were not detected.

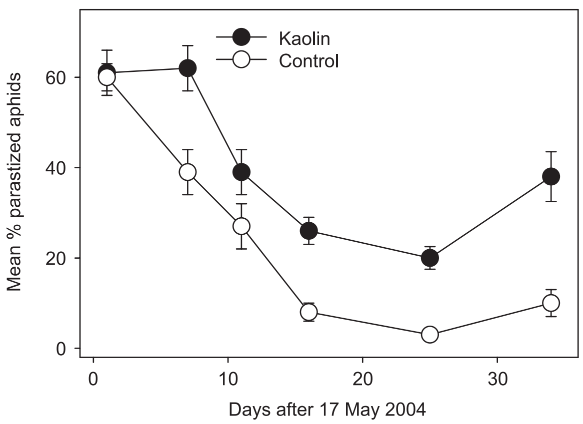

Figure 2 Parasitism of cotton aphids by *Lysiphlebus* spec. on cotton grown in kaolin-treated and control plots, Cameron County, Texas; n = 5 leaves per plot.

During 2004, the percentages of aphid mummies in the kaolin-treated cotton (upper leaves, 8.9 ± 1.5%; lower leaves, 8.7 ± 1.6%) and the control (upper leaves, 5.9 ± 3.1%; lower leaves, 6.7 ± 1.6%) were not different. During 2005, the numbers of mummies was ≤3 in the treated and control plots and treatment differences were not detected on upper or lower leaves.

Color

In 2004, colored pan traps indicated that cumulative numbers of alate cotton aphids were 2.3-fold more abundant in the green pan traps than in the white pans ($F_{2,27}$ = 3.54, P = 0.0430), and numbers in the yellow pans were intermediate (Figure 3A). Cotton aphids were 3.3- and 2.7-fold more abundant during 2005 in the green and yellow pan traps, respectively, than in the white pan traps ($F_{2,27}$ = 8.38, P = 0.0015; Figure 3B).

Discussion

Treatment differences in this study were independent of plant height and number of nodes per plant. Kaolin-treated cotton plots were more heavily infested by cotton aphids than control cotton plants.

Kaolin particle film reduces canopy, leaf, and fruit temperatures in orchard crops such as apple, *Malus sylvestris* var. *domestica*, presumably because kaolin reflects radiation (Glenn et al., 1999, 2001, 2002). Grapefruit, *Citrus paradisi* L., leaves treated with kaolin were ~3 °C cooler than non-treated controls (Jifon & Sylvertsen, 2003). Kaolin-treated bean, *Phaseolus vulgaris* L., leaves were 0.6 °C cooler than the non-treated control (Tworkoski et al., 2002), and in cotton, kaolin-treated canopy temperature was 1.2 °C lower than that of non-treated controls (Makus, 2000).

Optimum temperatures for cotton aphid development have been reported as being 26.7 °C (Henneberry et al., 2000), 27.5 °C (Akey & Butler, 1989), and 30 °C (Xia et al., 1999). Isely (1946) determined that cotton aphid development time increases at temperatures >27.8 °C and that reproduction is low at temperatures between 22.2 and 32.2 °C with the optimum temperature for reproduction being 20 °C. Komazaki (1982) reported that longevity of cotton aphids declined at temperatures >15 °C. Xia et al. (1999) found that survivorship to adulthood and fecundity of cotton aphids was greatest at 25 °C. The 4.5–7.6% lower temperatures on the ventral surfaces of kaolin-treated cotton leaves in our study likely favored the greater cotton aphid populations by enhancing reproduction and survivorship.

Numbers of cotton aphid predators, such as ladybird beetles (Coleoptera: Coccinellidae), minute pirate bugs (Heteroptera: Anthocoridae), and green lacewings (Neuroptera: Chrysopidae), are not affected by kaolin

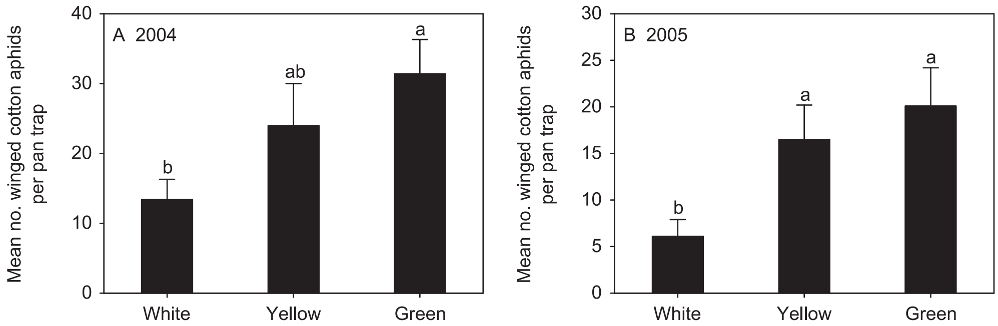

Figure 3 Mean (+ SE) numbers of alate cotton aphids found in white, yellow, and green pan traps during (A) 2004 and (B) 2005 in Hidalgo County, Texas; n = 10. Bars capped with different letters are significantly different ($P<0.05$), one-way analysis of variance, Tukey's honestly significant difference.

application to cotton (Showler & Sétamou, 2004), but kaolin treatment was associated with either negligible or heightened hymenopterous parasitism of cotton aphids. In both scenarios, parasitism did not contribute toward the greater numbers of aphids observed in the kaolin treatment.

Alate aphids have preferences for some colors over others (Kring, 1967; Roach & Agee, 1972; Fereres et al., 1999). For example, alate cotton aphids are caught in yellow pan traps more than in traps of other colors, but white was not tested (Webb et al., 1994; Idris et al., 2002). Mulching crops with reflective material such as aluminum foil or white plastic reduces the number of aphids landing on crop plants (Corsoro et al., 1980). Similarly, whitewashes and white particle films applied to crops have been associated with reduced populations of aphids (Bar-Joseph & Frenkel, 1983; Lowery et al., 1990; Cottrell et al., 2002). Our study shows that alate cotton aphids do not prefer white, which suggests that the greater cotton aphid populations in kaolin-treated plots were not likely related to color.

Kaolin particle film protects crops against some pest arthropods (Bar-Joseph & Frenkel, 1983; Glenn et al., 1999; Knight et al., 2000; Lapointe, 2000; Unruh et al., 2000), including aphids (Puterka et al., 2000; Cottrell et al., 2002). In cotton, kaolin reduces boll weevil and beet armyworm injury to buds and leaves, respectively (Showler, 2002, 2003). Despite the potential uses of kaolin on plants as a protectant against some pests and heat stress (Glenn et al., 1999; Knight et al., 2000; Unruh et al., 2000; Showler, 2002; Thomas et al., 2004), our study suggests that kaolin can exacerbate infestations of cotton aphids.

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